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Two new polypore species from the southwestern USA: *Fomitiporia fissurata* and *F. deserticola*

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Abstract — Based on molecular evidence and morphological studies, two new *Fomitiporia* species are described from southwestern USA. *Fomitiporia fissurata* sp. nov., on living *Quercus,* was previously misdetermined as *F. robusta* and is the only oak-inhabiting *Fomitiporia* species in the region. *Fomitiporia deserticola* sp. nov. grows on cacti and desert shrubs in Arizona and was previously misdetermined as *F. texana,* which is a species found only on juniper.

Key words — *Basidiomycota, Hymenochaetales, Hymenochaetaceae,* molecular taxonomy

Introduction

Fomitiporia Murrill (*Hymenochaetales, Basidiomycota*) forms a monophyletic clade within *Hymenochaetaceae* and is characterized by a perennial habit, dextrinoid and cyanophilous basidiospores, and absence of setae in most species (Dai et al. 2008; Dai 2010). Over the years, the interpretation of *Fomitiporia* in the USA has changed and evolved. Murrill (1907, 1908) described many American species that were not accepted by subsequent mycologists. During the most of the 20th century, the European species *F. robusta* (P. Karst.) Fiasson & Niemelä, *F. punctata* (P. Karst.) Murrill, and *F. hartigii* (Allesch. & Schnabl) Fiasson & Niemelä were reported throughout the United States. Only *F. texana* (Murrill) Nuss and *F. sonorae* (Gilb.) Y.C. Dai from southwestern USA were recognized as endemic American species (Gilbertson & Ryvarden 1987; Dai et al. 2001).

Recently, the presence of *F. robusta* and *F. punctata* in southern, western, and eastern USA has been questioned (Fischer & Binder 2004; Vlasák & Kout

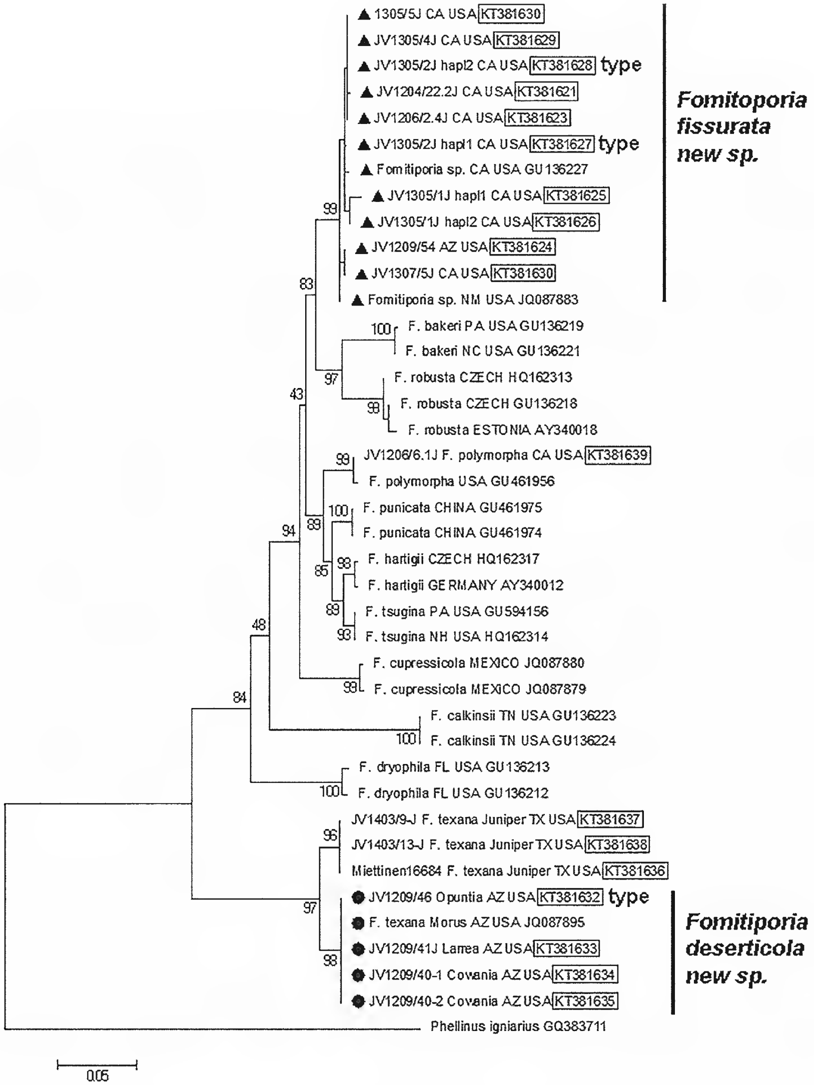
2011a) whereas other species, described by Murrill, have been confirmed. For example, recognition of resupinate species *Fomitiporia dryophila* Murrill, *F. langloisii* Murrill, and *F. maxonii* Murrill has been supported by molecular phylogenetics (Decock et al. 2007). Pileate species *F. bakeri* (Murrill) Vlasák & Kout growing on birch and *F. calkinsii* (Murrill) Vlasák & Kout growing on oak from the eastern USA have also been confirmed (Vlasák & Kout 2011a). In addition, two new species—*F. cupressicola* Amalfi et al. growing on *Cupressus arizonica* in northern Mexico and *F. polymorpha* M. Fisch. on *Salix* from the USA Pacific Coast—have been described (Fischer & Binder 2004; Amalfi et al. 2012). In these studies, researchers noted that DNA sequence data, ecological preferences, and biogeographical data were important in species characterization because distinguishing microscopic features were absent.

Overholts (1953) realized that a peculiar form of *Fomes robustus* [≡ *Fomitiporia robusta*], which was "less developed and nodulose-sessile," occurred on oaks in the western USA. Vlasák & Kout (2011a), who obtained a sample of this taxon from California (voucher JV 0407/16-J), discovered that its ITS rDNA sequence differed from all previously described *Fomitiporia* species. Amalfi et al. (2012) obtained the same ITS sequence from a collection from New Mexico designated *Fomitiporia* PS1 (phylogenetic species 1). We have since collected many specimens of this oak-restricted and relatively common fungus from southern California and Arizona, and describe it below as a new species, *F. fissurata.*

Davidson & Mielke (1947) identified a different taxon found on cacti and other desert plants in Arizona as a variety of *Fomes robustus.* Based on studies of pure cultures, they concluded it was not conspecific with *F. texana,* which is known from the same region but grows on juniper. *Pyropolyporus texanus* [≡ *Fomitiporia texana*] was considered conspecific with *Fomes robustus* by Lowe (1957) and Lowe & Gilbertson (1961) but were later accepted as distinct species, with the taxon growing on desert plants treated as conspecific with *F. texana* (Gilbertson & Canfield 1972; Gilbertson & Ryvarden 1987). We collected *Fomitiporia* specimens from both juniper and desert plants in Texas and Arizona and conclude that they represent separate species. We describe the taxon growing on desert plants as the new species *Fomitiporia deserticola.*

Materials & methods

Samples were collected in July 2004, spring and fall 2012, May 2013, and March 2014 at various localities in California and Arizona. The specimens were dried and microscopically examined in Melzer's reagent (IKI) and 5% KOH. All collected specimens are deposited in herbarium of Josef Vlasak (JV); types deposited in Prague Museum herbarium, Czech Republic (PRM). DNA isolation, nuclear ribosomal DNA


1305/5J CA USA KT381630
JV1305/4J CA USA KT381629
JV1305/2J hapl2 CA USA KT381628 type
JV1204/22.2J CA USA KT381621
JV1206/2.4J CA USA KT381623
JV1305/2J hapl1 CA USA KT381627 type
Fomitiporia sp. CA USA GU136227
JV1305/1J hapl1 CA USA KT381625
JV1305/1J hapl2 CA USA KT381626
JV1209/54 AZ USA KT381624
JV1307/5J CA USA KT381630
Fomitiporia sp. NM USA JQ087883
Fomitoporia fissurata new sp.
F. bakeri PA USA GU136219
F. bakeri NC USA GU136221
F. robusta CZECH HQ162313
F. robusta CZECH GU136218
F. robusta ESTONIA AY340018
JV1206/6.1J F. polymorpha CA USA KT381639
F. polymorpha USA GU461956
F. punicata CHINA GU461975
F. punicata CHINA GU461974
F. hartigii CZECH HQ162317
F. hartigii GERMANY AY340012
F. tsugina PA USA GU594156
F. tsugina NH USA HQ162314
F. cupressicola MEXICO JQ087880
F. cupressicola MEXICO JQ087879
F. calkinsii TN USA GU136223
F. calkinsii TN USA GU136224
F. dryophila FL USA GU136213
F. dryophila FL USA GU136212
JV1403/9-J F. texana Juniper TX USA KT381637
JV1403/13-J F. texana Juniper TX USA KT381638
Miettinen16684 F. texana Juniper TX USA KT381636
JV1209/46 Opuntia AZ USA KT381632 type
F. texana Morus AZ USA JQ087895
JV1209/41J Larrea AZ USA KT381633
JV1209/40-1 Covania AZ USA KT381634
JV1209/40-2 Covania AZ USA KT381635
Fomitiporia deserticola new sp.
Phellinus igniarius GQ383711
99
83
43
100
97
99
99
100
89
94
99
85
89
93
48
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84
100
100
96
97
99
0.05

Fig. 1: Phylogenetic relationships of 36 *Fomitiporia* specimens inferred from ITS rRNA sequences. *Phellinus igniarius* was used as outgroup. Topology from maximum likelihood (ML) analysis. Support values along branches from ML bootstrap (500 replicates). Branch lengths are drawn proportional to the number of substitutions per site. Triangles and black circles indicate specimens of new species. GenBank numbers are presented at the end of taxon labels with new sequences boxed.

ITS region sequencing, and comparative phylogenetic analyses methods follow Vlasák & Kout (2011b). The evolutionary history was inferred by using the Maximum Likelihood method; the analyses were conducted using MEGA 6 (Tamura et al. 2013).

Results

Phylogenetic analysis

Twenty ITS sequences of *Fomitiporia* specimens from California and Arizona were generated for this study. A complete *Fomitiporia* ITS dataset, which included 23 *Fomitiporia* sequences retrieved from GenBank and represented all pileate *Fomitiporia* species occurring in the USA, produced an alignment with 833 characters, of which 180 were parsimony informative. Phylogenetic analyses strongly support all pileate *Fomitiporia* specimens collected on oak in California and Arizona within the clade of the new species *F. fissurata* (Fig. 1). Species in this clade are sister to the European species *F. robusta* and the American species *F. bakeri,* as expected from their morphological characters. *Fomitiporia* specimens from various desert plants in Arizona (including cacti) comprise another strongly supported clade, representing the new species *F. deserticola,* which is sister to the juniper-dwelling *F. texana* (Fig. 1).

Taxonomy

Fomitiporia fissurata Vlasák, **sp. nov.** Figs 2, 3

MycoBank MB 813966

Differs from *Fomitiporia robusta* by its broader, rounded pileal margin, pileal surface with deep arboriform fissures even in juvenile basidiomata, smaller basidiospores, and a different ITS rDNA sequence.

Type: USA. California: Cleveland National Forest, Mt. Laguna, *Quercus* sp. (*Fagaceae*), 18 May 2013, J. Vlasák Jr. (**Holotype**, PRM 922626; **isotype**, JV1305/2-J; GenBank KT381627, KT381628).

Etymology: *fissurata* (Lat.): referring to striking fissures on pileal surface of the fungus.

Basidiomes perennial, pileate, arising from a black, cracked, crust-like outgrowth on the substrate, ungulate, up to 18 × 10 × 12 cm; margin 3–6 cm broad, rounded; upper surface gray to blackish, often with white spore deposits, at first glabrous and with a few wide sulcate zones, soon indurated to 1 cm deep and cracking up irregularly, creating deep, often arboriform fissures; pore surface yellowish brown; pores circular, 4–6 per mm, with thin to thick, entire dissepiments; context yellowish-brown, shining at first, then woody hard, up to 5 cm thick, with distinct white radial veins in older parts resulting in a marmorate appearance of the context close to the substrate attachment; tube layers distinct, light brown, tubes becoming white within from hyphae growing in the tubes, woody, each layer up to 1 cm thick.

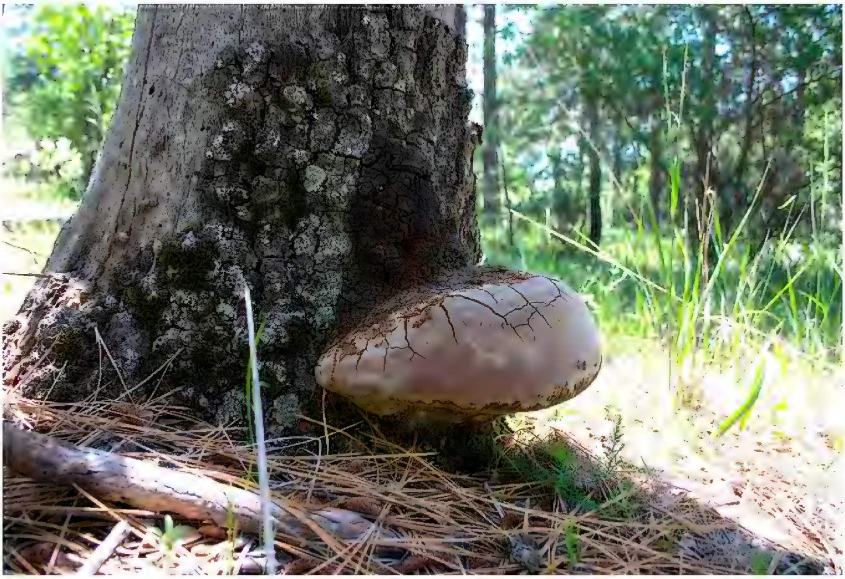

Fig. 2: *Fomitiporia fissurata* specimen: PRM 922626, holotype (JV1305/2-J, isotype)

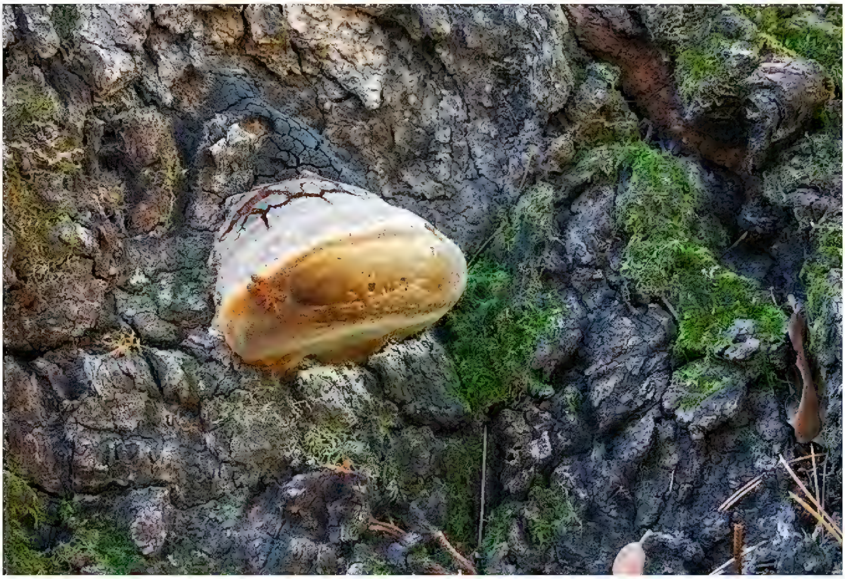

Fig. 3: *Fomitiporia fissurata* specimen: JV1209/54 (split collection: PRM 922627)

Hyphal system dimitic, skeletal hyphae brownish, thick-walled, 2–4 µm diam., generative hyphae hyaline, thin-walled, simple septate, 2–4 µm diam. Setae absent. Basidia broadly ellipsoid, 4-sterigmate, 12–15 × 7–9 µm, simple septate at the base. Basidiospores subglobose, hyaline, smooth, thick-walled, strongly dextrinoid, 6–7 × 5–6(–6.5) µm. White rot on living *Quercus*.

Distribution & ecology. Common on living *Quercus* spp. in the US southwest (California, Arizona, New Mexico); causing a white rot. No other pileate *Quercus*-dwelling *Fomitiporia* species is known in the region.

Additional specimens examined: **USA. California**: Santa Cruz, Henry Covell Redwoods State Park, *Quercus*, Jul 2004, J. Vlasák Jr. (JV0407/16J; GenBank GU136227, GU136228); Thousand Oaks, Malibu Creek State Park, *Quercus*, 22 Apr 2012, J. Vlasák Jr. (JV1204/22.2J; GenBank KT381621, KT381622); Saratoga, Castle Rock State Park, *Quercus*, 2 Apr 2006, J. Vlasák Jr. (JV1206/2.4J; GenBank KT381623); Cleveland National Forest, Pine Valley County Park, *Quercus*, 18 May 2013, J. Vlasák Jr. (JV1305/1J; GenBank KT381625, KT381626); Escondido, Mt. Palomar, *Quercus*, 23 May 2013, J. Vlasák Jr. (JV1305/4J; GenBank KT381629); Palm Springs, Mt. San Jacinto, *Quercus*, 25 May 2013, J. Vlasák Jr. (JV1305/5J; GenBank KT381630); **Arizona**: Santa Rita Mts., Madera Canyon, *Quercus*, 2 Sep 2012, J. Vlasák (JV1209/19); Chiricahua Mts., Chiricahua Nat. Monument Visitor Center, *Quercus*, 5 Sep 2012, J. Vlasák (JV1209/54, PRM 922627; GenBank KT381624); Cochise Stronghold National Monument, *Quercus*, 17 Jul 2013, J. Vlasák Jr. (JV1307/5J; GenBank KT381631).

Comments. *Fomitiporia robusta,* which occurs in Europe, differs from *F. fissurata* by its pileal surface mostly covered with green algae and becoming cracked only in old basidiomes. The cracks do not form arboriform fissures. In addition, a black crust does not develop around the *F. robusta* basidiome, which has a narrower rounded margin compared to *F. fissurata*. Finally, *F. robusta* produces larger basidiospores (6–8.5 × 5.5–7 µm). *Fomitiporia bakeri* also resembles *F. fissurata* but is found only on birch in the eastern and central USA. *Fomitiporia calkinsii,* which grows on oaks in the southeastern USA, has a relatively sharp margin, a more thinly hardened crust that is rarely or inconspicuously cracked, and a darker brown context and tube layers. *Fomitiporia polymorpha,* growing primarily on willows in the western USA, develops small, bulbous basidiomes, and *F. hartigii* and *F. tsugina* are known from gymnosperms.

Fomitiporia deserticola Vlasák, sp. nov. Figs 4–6(top)

MycoBank MB 813967

Differs from *Fomitiporia texana* by its angular, thin-walled pores, a different ITS rDNA sequence, and smaller basidiospores.

Type: USA. Arizona: Tanque Verde, *Opuntia versicolor* Engelm. ex Toumey (*Cactaceae*), 4 Sep 2012, J. Vlasák 1209/46 (**Holotype**, PRM 934073; **isotype**, JV1209/46; GenBank KT381632).

Etymology: *deserticola* (Lat.): referring to growth on desert plant substrates.

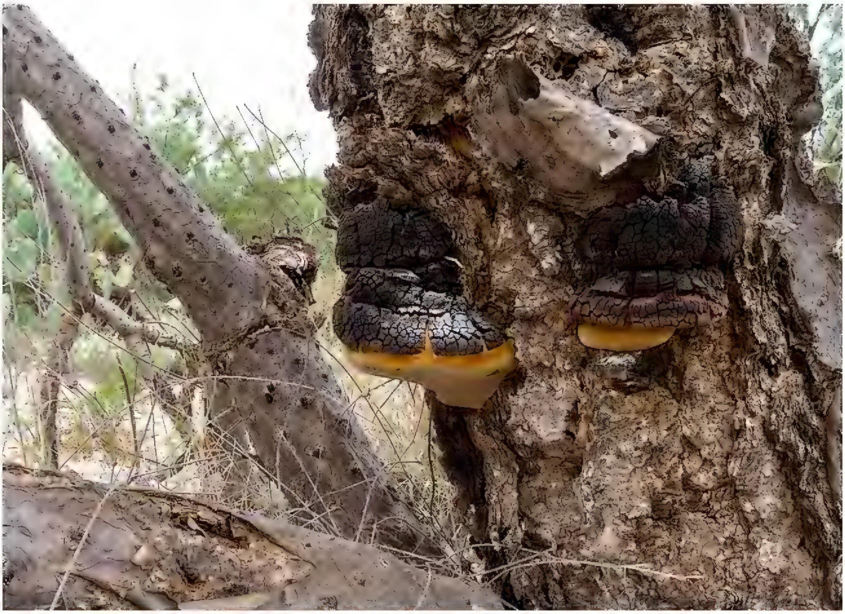

Fig. 4: *Fomitiporia deserticola* specimens:
JV1209/46, isotype (left); PRM 934073, holotype (right).

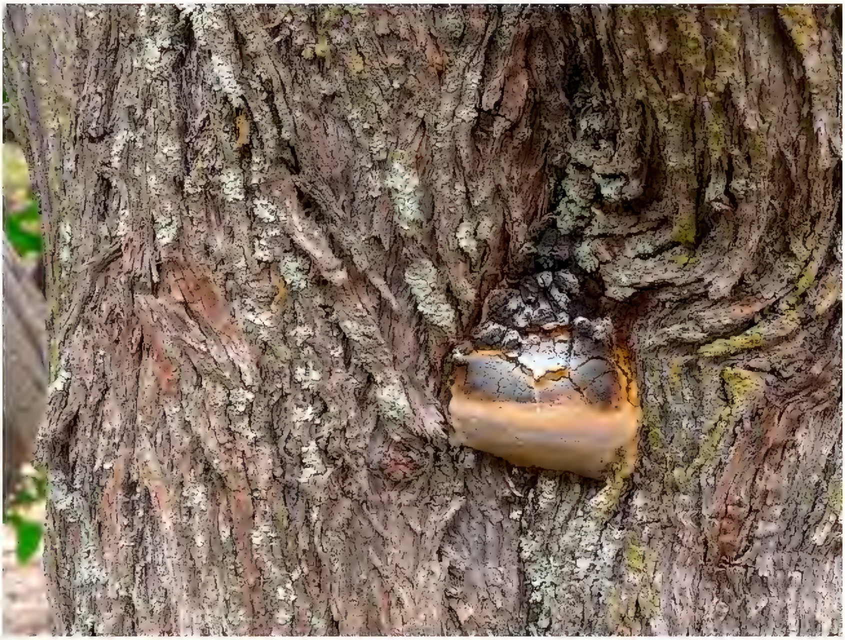

Fig. 5: *Fomitiporia deserticola* specimen: JV1209/40.

Basidiomes perennial, pileate, distinctly ungulate, small to medium-sized, usually 2–4 cm in diam., but sometimes up to 8 × 8 × 8 cm; upper surface at first dark brown, tomentose, soon becoming blackened and deeply rimose, usually with white spore deposits and cracks often partially filled by current year context tissue; margin rounded, yellowish brown, tomentose; pore surface pale brown; pores angular, somewhat irregular, 4–6 per mm, with thin to thick, entire dissepiments; context woody hard, brown, up to 1 cm thick; tube layers distinct, pale brown, becoming stuffed with light-colored mycelium, each layer up to 1 cm thick.

Hyphal system dimitic, skeletal hyphae brownish, thick-walled, 2–4 µm diam, generative hyphae hyaline, thin-walled, simple septate, 2–4 µm diam. Cystidioles abundant, with an inflated base up to 8 µm diam and a slender neck, 10–30 µm long and about 2 µm thick. Setae rare, similar to cystidioles but thick-walled. Basidia subglobose, 4-sterigmate, 9–12 × 8–10 µm, simple septate at the base. Basidiospores subglobose, hyaline, smooth, thick-walled, strongly dextrinoid, 6–7.5 × 5.5–7 µm.

Distribution & ecology. On living cacti and desert shrubs in Arizona, causing a white rot.

Additional specimens examined:

Fomitiporia deserticola**: USA, Arizona**: Tanque Verde, *Cowania stansburiana* Torr. (*Rosaceae*), 4 Sep 2012, J. Vlasák Jr. (JV 1209/40, GenBank KT381634, KT381635); *Larrea tridentata* (Sessé & Moc. ex DC.) Coville (*Zygophyllaceae*), 4 Sep 2012, J.Vlasák Jr. (JV1209/41J; GenBank KT381633); J.Vlasák Jr. (JV1209/42J).

Fomitiporia texana**: USA, Texas**: Austin, *Juniperus ashei* J. Buchholz (*Cupressaceae*), 15 Aug 2013, O. Miettinen 16684 (JV1308/15; GenBank KT381636); Balcones Canyonlands National Wildlife Ref., *Juniperus* sp., 21 Mar 2014, J. Vlasák Jr. (JV1403/9-J; GenBank KT381637); Pedernales Falls State Park, *Juniperus* sp., 22 Mar 2014, J. Vlasák Jr. (JV1403/13-J; GenBank KT381638).

Comments. *Fomitiporia texana,* which occurs in the same region as *F. deserticola,* can be distinguished by round thick-walled pores (Fig. 6, bottom), cracks on pileal surface not filled with context tissue from current year, larger basidiospores (mostly 8 µm diam), and host specific on juniper. Davidson & Mielke (1947) have also shown that culture characteristics of the cactus and juniper taxa are different.

Gilbertson & Lindsey (1975) cited setae as characteristic of *F. texana,* although setae were mentioned neither in the original description (Murrill 1908) nor in the description of *Fomes robustus* on cacti (Davidson & Mielke 1947). Gilbertson & Ryvarden (1987) suggested that these structures represent just cystidioles with thickened walls, and we agree with their interpretation.

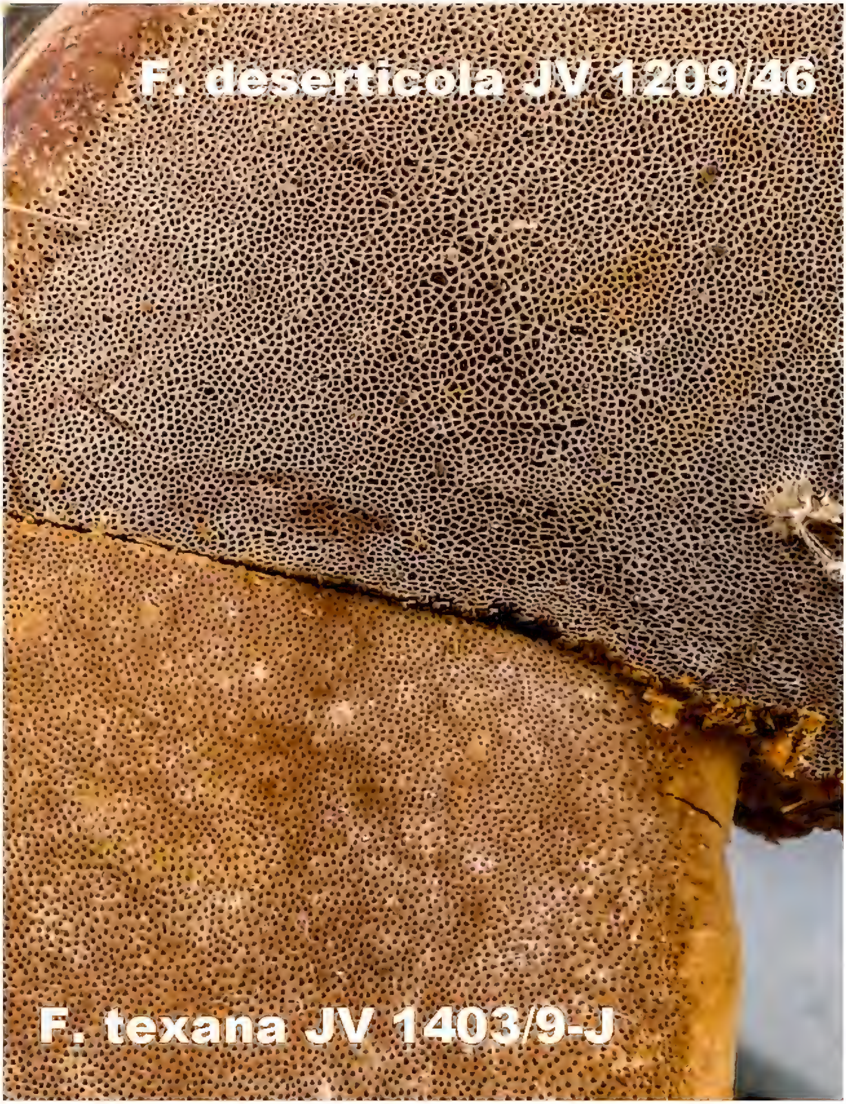

Fig. 6: Comparison of pores of *Fomitiporia deserticola* and *F. texana*.

Setae are uncommon; as they have been observed in about half of the specimens of both *F. texana* and *F. deserticola,* their value for species differentiation is limited.

Macroscopic features key to pileate *Fomitiporia* species occurring in the USA

1	Species with detached upper margin on otherwise resupinate basidiocarp	2
1	Distinctly pileate species, with mostly large, sessile or ungulate pilei	4
2	On *Tsuga*	*F. tsugina*
2	On dicotyledonous hosts	3
3	On *Dodonea viscosa* in a small area in Arizona	*F. sonorae*
3	On *Quercus* in southern USA from Florida to Texas	*F. dryophila*
4	On *Betula* in northeastern and midwestern USA	*F. bakeri*
4	On other substrates	5
5	On coniferous hosts	6
5	On dicotyledenous hosts	7
6	On *Juniperus* in southern Texas and Arizona	*F. texana*
6	On living *Cupressus* in Mexico and southwestern USA	*F. cupressicola*
7	On desert shrubs and cacti in southern Arizona	*F. deserticola*
7	On *Quercus*	8
8	In southeastern USA, margin of typical pilei 0.5–1 cm thick, pileus crust not at all or indistinctly cracked	*F. calkinsii*
8	In southwestern USA, pileal margin rounded and 2–5 cm thick, crust deeply, irregularly cracked in old and juvenile pilei	*F. fissurata*

Discussion

With the addition of two new *Fomitiporia* species from the western USA, there are now nine North American pileate species. We do not include *F. robusta* nor *F. hartigii* in our key, because neither Eurasian species occurs in North America (Vlasák & Kout 2011a; Brazee 2013). Our DNA sequence data results support the conclusions by Amalfi et al. (2012) and others that geography, habitat, and host relationships are important factors in *Fomitiporia* speciation. Accordingly, a key based on morphology, host and distribution only (see above) can be used successfully to identify pileate species of *Fomitiporia* in North America. Nevertheless, molecular methods are necessary to delineate cryptic species.

Acknowledgments

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